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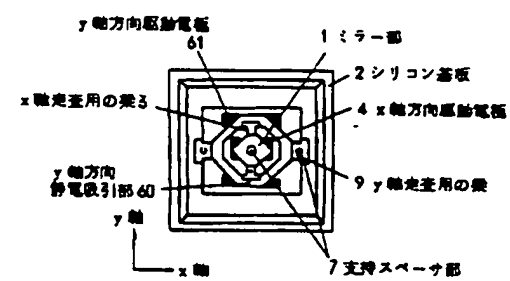
(54)【発明の名称】　静電力駆動小型光スキャナ

(57)【要約】

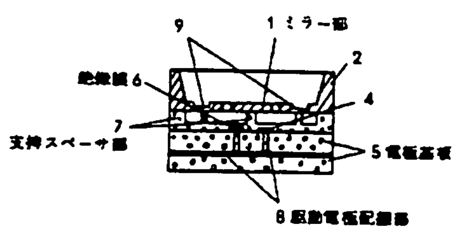
【目的】　本発明は、レーザレーダ用のスキャナとして、またファクシミリやプリンターの書き込み用として、また将来の光情報処理分野に利用する1軸方向，2軸方向走査光スキャナに関するもので、構造が複雑で、駆動機構が大きいという従来の問題点を解決し、半導体プロセス加工を用いてミラーや駆動機構を形成し、超小型の光スキャナを提供するものである。

【構成】　半導体レーザ光を反射し、X軸，Y軸方向に変位可能なシリコン基板で形成されたミラー部と、ミラー部を両側から支持するシリコン基板で形成された梁部と、ミラー部裏面に対向する位置に配置されたX軸，Y軸方向駆動電極と、電極基板と、駆動電極を絶縁するための絶縁膜と、ミラー部と駆動電極間のギャップを決める支持スペーサ部からなり、さらに前記駆動電極の配線部が、ミラー部に対して駆動電極よりも距離があり、静電力がミラー部に作用しない平面上に形成されていることにより、超小型の2軸方向走査可能な光スキャナを提供する。

(a)



(b)



【特許請求の範囲】
【請求項1】 半導体レーザ光を反射し、X軸方向に変位可能なシリコン基板で形成されたミラー部と、前記ミラー部と一体で構成されているが、ミラー部とは厚さが必ずしも同一ではなく、ミラー部を両側から支持するシリコン基板で形成されたX軸走査用の梁と、前記X軸走査用の梁と一体でその外側に形成され、前記ミラー部と直交するY軸方向に変位可能な静電吸引部と前記静電吸引部と一体で構成されているが、静電吸引部とは厚さが必ずしも同一でなく、静電吸引部を両側から支持するシリコン基板で形成されたY軸走査用の梁と、前期ミラー部を駆動するために、ミラー部や前記静電吸引部の裏面に対向する位置に配置されたX軸，Y軸方向駆動電極と、前記駆動電極が形成されている電極基板と、前記駆動電極とミラー部の間に存在し、駆動電極を絶縁するための絶縁膜と、ミラーの変位に対しミラーのたわみが生じないように支持し、ミラー部と駆動電極間のギャップを決める支持スペーサ部からなり、さらに前記駆動電極の配線部が、ミラー部に対して駆動電極よりも距離があり、静電力がミラー部に作用しない平面上に形成されていることを特徴とする2軸方向走査可能な静電力駆動小型光スキャナ。
【請求項2】 半導体レーザ光を反射し、1軸方向に変位可能なシリコン基板で形成されたミラー部と、前記ミラー部と一体で構成されているが、ミラー部とは厚さが必ずしも同一ではなく、ミラー部を両側から支持するシリコン基板で形成された梁部と、前記梁部と一体で構成され、ミラー部とは別に梁部にねじりを生じさせるため複数本（組，段）形成された静電吸引部と、前記ミラー部および静電吸引部に対向する位置に配置された駆動電極と、前記駆動電極が形成されている電極基板と、前記駆動電極とミラー部の間に存在し、駆動電極を絶縁するための絶縁膜と、ミラーの変位に対しミラーのたわみが生じないように支持し、ミラー部と駆動電極間のギャップを決める支持スペーサ部からなる1軸方向走査可能な静電力駆動小型光スキャナ。
【請求項3】 ミラー部の上に反射防止膜をつけたガラス基板を接着し、ガラス基板と電極基板にはさまれたミラー部の存在する空間が真空であることを特徴とする第1項，第2項記載の静電力駆動光スキャナ。
【請求項4】 前記してきた第1項，第2項記載の静電力駆動光スキャナのミラーが、同一面内に複数個が直線的に、または平面的に配列したことを特徴とした静電力駆動小型光スキャナ。

【発明の詳細な説明】
【0001】
【産業上の利用分野】本発明は、物体の探査、把握を行うためのレーザレーダ用のスキャナとして、またファクシミリやプリンターの書き込み用として、また将来の光コンピューティングに代表される光情報処理分野に利用する1軸方向，2軸方向走査光スキャナに関するものである。
【0002】
【従来の技術】以下、従来の2軸方向走査光スキャナについて図8，9，10をもちいて説明する。図8，9，10において、51はレーザ光源、52はX軸方向ミラー、53はY軸方向ミラー、54はポリゴンミラー、55はディスク型ホログラムスキャナである。以上のように構成された2軸方向走査光スキャナについて、その動作について説明する。図8は、レーザ光源51からでたレーザ光がX軸方向のミラー52とY軸方向のミラー53を回転変位させることにより2軸方向走査する、ガルバノメータスキャナを二つ組み合わせた構成や、図9に示すようにポリゴンミラー54とガルバノメータスキャナにより回転変位するY軸方向ミラー53を組み合わせた構成や、図10に示すようにディスク型ホログラムスキャナ55とガルバノメータスキャナにより回転変位するY軸方向ミラー53を組み合わせた構成が知られている。
【0003】つぎに、近年の1軸方向走査の光スキャナについては、マイクロマシンの研究が盛んに行われるようになり、シリコンマイクロマシニングを用いた小型光スキャナが作られている。例えば、静電型シリコンねじり振動子（富士電気，中川ほか）、日本機械学会第68期全国大会講演会講演論文集Ｖｏｉ．Ｄ、（１９９０）などである。
【0004】以下、従来の1軸走査の小型光スキャナについて、図11，12を用いて説明する。図11は、静電型シリコンねじり振動子の外観図である。振動子41は、可動板42とスパンバウンド43と枠44からなり、厚さ0．3mmのシリコンからエッチングにより一体形成している。可動板42とスパンバウンド43の厚さは20μmである。シリコン振動子41は、電極を形成したガラス基板45にスペーサ46を挟んで接着している。
【0005】図12は、静電型シリゴンねじり振動子の運動状態を示した断面図である。S字型のスパンバウンド43で支持された可動板42と電極間に電圧を印加すると、両者の間に静電力が働き、可動板42はスパンバウンド43を軸として電極に静電吸引され振動する。
【0006】
【発明が解決しようとする課題】しかしながら、2軸方向走査光スキャナについては、上記の構成では、数多くの部品からなり構造が複雑であり、又ミラー部の駆動のためのアクチュエータが大きく、全体を小型化することが困難である。
【0007】静電型シリコンねじり振動子の場合は、小型であるが、2軸方向走査は出来ない。また1軸方向走査光スキャナとして考えると、走査角度を増加させるにしたがい、駆動電圧が高くなる。逆に、駆動電圧を制限

して走査角度増加させると、スパンバウンドの機械的強度が低下するなどの問題がある。

【0008】本発明は、上記従来例の課題を解決するもので、半導体プロセス加工を用いて、ミラーやアクチェータを形成し、超小型，低電圧駆動（広走査角度）の1軸方向走査，2軸方向走査光スキャナを提供することを目的とする。

【0009】

【課題を解決するための手段】この目的を達成するために本発明は、半導体レーザ光を反射し、X軸，Y軸方向に変位可能なシリコン基板で形成されたミラー部と、ミラー部を両側から支持するシリコン基板で形成された梁部と、前期ミラー部を駆動するために、ミラー部裏面に対向する位置に配置されたX軸，Y軸方向駆動電極と、前記駆動電極が形成されている電極基板と、前記駆動電極とミラー部の間に存在し、駆動電極を絶縁するための絶縁膜と、ミラー部と駆動電極間のギャップを決める支持スペーサ部からなり、さらに前記駆動電極の配線部が、ミラー部に対して駆動電極よりも距離があり、静電力がミラー部に作用しない平面上に形成されている2軸方向走査可能な光スキャナ構造や、梁部と一体で構成され、ミラー部とは別に梁部にねじりを生じさせるため複数本（組，段）形成された静電吸引部と、前記ミラー部および静電吸引部に対向する位置に配置された駆動電極を形成した構造の1軸走査可能な光スキャナや、ミラー部の上に反射防止膜をつけたガラス基板を接着し、ガラス基板と電極基板にはさまれたミラー部の存在する空間が真空である構造や、前記の静電力駆動光スキャナのミラーが、同一面内に複数個が直線的に、または平面的に配列した構造を有するものである。

【0010】

【作用】本発明は、上記構成によって、シリコン基板上に形成されたミラーが、駆動電極に電圧を印加することで、X軸，Y軸の2軸方向走査可能となり、半導体レーザ光は二次元走査される。全体が超小型な2軸方向走査光スキャナを提供することができる。また複数本の静電吸引部を持つことにより、従来よりも低電圧で、広走査角度の1軸方向走査光スキャナを提供することができる。さらに、これら光スキャナのミラー部を真空中で動作させることにより、高速応答が可能になる。そして、これらミラーを、単一ではなく直線的にまた平面的に配列することで、プリンターの書き込み用や光情報分野用として、従来にない小型でまったく新しい光スキャナデバイスを提供することができる。

【0011】

【実施例】

（実施例1）以下、本発明の第1の実施例について図面を参照しながら説明する。図1は、本発明の第1の実施例における小型の2軸方向走査可能な静電力駆動光スキャナの（a）平面図と（b）断面図である。

【0012】図1において、1はミラー部、2はシリコン基板、3はX軸走査用の梁、4はX軸方向駆動電極、5は電極基板、6は絶縁膜、7は支持スペーサ部、8は駆動電極配線部、9はY軸走査用の梁、60はY軸方向静電吸引部、61はY軸方向駆動電極である。　ミラー部1は、X軸走査用の梁3と一体で構成され、さらにX軸走査用の梁3の他の端は、Y軸方向静電吸引部60と一体で構成され、Y軸方向静電吸引部60は、Y軸走査用の梁9と一体で構成され、さらにY軸走査用の梁9の他の端は、シリコン基板2と一体で構成されており、これらすべてシリコンで形成されている。ミラー部1の下部にはX軸方向駆動電極4が、またY軸方向静電吸引部60の下部にはY軸方向駆動電極61が配置されており、これら駆動電極は、電極基板5に形成されている。駆動電極配線部8は、ミラー部1などに対して駆動電極よりも距離を隔てて形成され、駆動電極配線部8による静電力がミラー部1に作用しないよう電極基板5の内部配線により形成されている。

【0013】電極基板5上のX軸方向駆動電極4とY軸方向駆動電極61と、ミラー部1とY軸方向静電吸引部60との間には、駆動電極の絶縁用の絶縁膜6とミラー部1を支え、ミラー部1と駆動電極間のギャップをきめる支持スペーサ部7が形成されており、支持スペーサ部7は、電極基板5上に形成されており、シリコン基板2は、支持スペーサ部7と接着されている。

【0014】以上のように構成された2軸方向走査可能な静電力駆動小型光スキャナについて、次にその動作について説明する。

【0015】ミラー部1は、X軸方向駆動電極4に電圧を印加することにより、その静電力を受け、X軸走査用の梁3と支持スペーサ部7を支点として、光をX軸方向に走査する動作をする。次にY軸方向駆動電極61に電圧を印加すると、Y軸方向静電吸引部60が、その静電力を受けて、Y軸走査用の梁9と支持スペーサ部7を支点として、光をY軸方向に走査する動作をする。ミラー部1はY軸方向静電吸引部60と一体となり光をY軸方向に走査する動作をする。以上の電圧印加を同時に行うことにより、ミラー部1で反射光を2軸方向走査することができる。

【0016】以上のように、本実施例によれば、シリコン基板2上に形成したミラー部1を、X軸，Y軸方向の駆動電極に電圧を印加することで、静電力により吸引させ、レーザ光を2軸方向走査可能な静電力駆動小型光スキャナを提供することができる。

【0017】（実施例2）以下、本発明の第2の実施例について図面を参照して説明する。図2は、本発明の第2の実施例における小型の1軸方向走査可能な静電力駆動光スキャナの（a）平面図と（b）断面図である。

【0018】図2において、1はミラー部、2はシリコン基板、10は第1の梁、11は第1の静電吸引部、1

2は第2の梁、13は第2の静電吸引部、14はミラー部の梁、15は支持スペーサ部、16は電極基板、17は絶縁膜、18はミラー駆動電極、19は第2の静電吸引部駆動電極、20は第1の静電吸引部駆動電極である。シリコン基板2上に、ミラー部1と一体でミラー部の梁14が形成され、ミラー部の梁14と一体で、前記ミラー部1を囲むように第2の静電吸引部13と第2の梁12が形成され、さらに第2の梁12と一体で前記の第2の静電吸引部13を囲むように第1の静電吸引部11と第1の梁10が形成されている。

【0019】図2の（b）に示すように、ミラー部1の下部には、ミラー駆動電極18が配置され、同様に第2の静電吸引部13の下部には、第2の静電吸引部駆動電極19が、第1の静電吸引部11の下部には、第1の静電吸引部駆動電極20が配置されている。これら駆動電極は電極基板16に形成されている。シリコン基板2と電極基板16との間には、駆動電極の絶縁用の絶縁膜17と、ミラー部1を支え、ミラー部1と駆動電極間のギャップを決める支持スペーサ部15が形成されている。電極基板16の上に支持スペーサ部15が形成され、シリコン基板2は、支持スペーサ部15と接着されている。

【0020】以上のように構成された1軸走査可能な静電力駆動小型光スキャナについて、次に、その動作について、図3を用いて説明する。図3は、1軸走査可能な静電力駆動小型光スキャナの動作を説明するための説明図である。

【0021】図3において、第1の静電吸引部駆動電極20に電圧を印加すると、第1の静電吸引部11が吸引され、第1の静電吸引部駆動電極20に密着する。このとき、第2の静電吸引部13およびミラー部1は、第1の静電吸引部11と同じだけ変位している。次に第2の静電吸引部駆動電極19に電圧を印加すると、第2の静電吸引部13が吸引され、第2の静電吸引部駆動電極19に密着する。このときミラー部1は、第2の静電吸引部13と同じだけ変位している。さらにミラー駆動電極18に電圧を印加すると、ミラー部1が吸引されて、ミラー駆動電極18に密着する。以上のように動作させることにより、ミラー部1だけを単体で変位させるよりも低電圧で駆動することができる。また同電圧であれば、各梁の部分ですこしづつねじれが生じることで、広い走査角度を得ることができる。

【0022】図4は、本発明の第2の実施例における小型の1軸方向走査可能な静電力駆動光スキャナの他のミラー部形状を示す平面図である。図4において、1はミラー部、21は第1の静電吸引部、22は第2の静電吸引部、23は第3の静電吸引部、24は第4の静電吸引部、25は支持スペーサ部である。

【0023】この形状においても、第1の静電吸引部から第4の静電吸引部まで順次電圧を印加することにより、ミラー部1は、低電圧駆動で、広い走査角度を得ることができる。また今回の例では、駆動電極は、静電吸引部に対応して分割して構成したが、全体をまとめて一つの電極としてもよい。ただし、分割することにより、より複雑で、高度な駆動制御を行うことができる。

【0024】以上のように、本実施例によれば、シリコン基板に形成したミラー部1とその周囲に形成した複数の静電吸引部を、前記ミラー部1および複数の静電吸引部に対応した駆動電極により、順次電圧を印加することにより、従来のミラー部1を単体で駆動するよりも、低電圧駆動ができ、また広い走査角度を得ることができる小型の1軸方向走査可能な静電力駆動光スキャナを提供することができる。

（実施例3）以下、本発明の第3の実施例について図面を参照しながら説明する。図5は、本発明の第3の実施例における小型の1軸または2軸方向走査可能な光スキャナの断面図である。図5において、1はミラー部、2はシリコン基板、4はX軸方向駆動電極、5は電極基板、7は支持スペーサ、8は駆動電極配線部、30は真空部、31はガラス基板である。

【0025】電極基板5にX方向駆動電極4とその駆動電極配線部8が形成されており、さらにその上に支持スペーサ部7が成形され、前記支持スペーサ部7とミラー部1を有するシリコン基板2が接着されており、さらにシリコン基板2の支持スペーサ部7と接着されている面と反対側の面に、反射防止膜をつけたガラス基板31が接合されており、接合の方法としては、真空チャンバ内において、ガラス基板31とシリコン基板2の陽極接合を行う。したがって、ミラー部1の周囲の空間は真空部30となる。

【0026】前記の構造において、駆動電極に電圧を印加し、ミラー部1を動作させると、真空中のため、応答性が向上する。またミラー部1の酸化もなく鏡面が保たれる。またミラー部1の上面にガラス基板31があることにより、ゴミなどに対しても強くなる。

【0027】以上のように、本実施例によれば、ガラス基板と電極基板にはさまれたミラー部の存在する空間が、真空であることにより、ミラー部の動作の応答性が向上し、またミラー面の酸化やゴミによる汚れにも強い小型の1軸または2軸方向走査可能な光スキャナを提供することができる。

【0028】（実施例4）以下、本発明の第4の実施例について図面を参照しながら説明する。図6は、本発明の第4の実施例における小型の1軸方向走査可能な光スキャナを複数個、直線的に配列したところを示す平面図である。

【0029】図6において、1はミラー部、32は1軸方向走査光スキャナ、33は第1列のミラーアレイ、34は第2列のミラーアレイ、37はY軸走査用の梁である。図6のように、Y軸走査用の梁37で支持されたミ

ラ-部1を持つ1軸方向走査光スキャナ32を、第1列のミラ-アレイ33のように配列し、さらに第2列のミラ-アレイ34を第1列のミラ-アレイ33に対して、ミラ-部1間ピッチの1／2だけずらして配列することにより、より高密度にミラ-部1を配列したのと同等の動作をさせることができる。このように配列したものは、プリンタ-などの書き込み用ヘッドとして、利用することができる。

【0030】図7は、本発明の第4の実施例における小型の2軸方向走査可能な光スキャナを複数個、平面的に配列したところを示す平面図である。図7において、1はミラ-部、35は2軸方向走査光スキャナ、36は面状配列光スキャナである。中央のミラ-部1を有する2軸方向走査光スキャナ35を平面的に配置し、面状配列光スキャナ36を構成した。この面状配列光スキャナ36は、非常に薄いディスプレイとして、また将来の光コンピューティング用の光情報処理素子として使用することが考えられる。

【0031】以上のように、本実施例によれば、1軸または2軸方向走査可能な光スキャナを複数個、直線的または平面的に配列したことにより、単一の光スキャナではできない小型で新しい光スキャナデバイスを提供することができる。

【0032】

【発明の効果】以上のように本発明は、半導体レーザ光を反射し、X軸，Y軸方向に変位可能なシリコン基板で形成されたミラ-部と、ミラ-部を両側から支持するシリコン基板で形成された梁部と、前記ミラ-部を駆動するために、ミラ-部裏面に対向する位置に配置されたX軸，Y軸方向駆動電極と、前記駆動電極が形成されている電極基板と、前記駆動電極とミラ-部の間に存在し、駆動電極を絶縁するための絶縁膜と、ミラ-部と駆動電極部間のギャップを決める支持スペ-サ部からなり、さらに、前記駆動電極部の配線部が、ミラ-に対して駆動電極よりも距離があり、静電力がミラ-部に作用しない平面状に形成されている2軸方向走査可能な光スキャナ構造や、梁部と一体で形成され、ミラ-部とは別に梁部にねじりを生じさせるため、複数本（組，段）形成させた静電吸引部と、前記ミラ-部および静電吸着部に対向する位置に配置された駆動電極を形成した構造の1軸走査可能な光スキャナや、ミラ-部の上に反射防止膜をつけたガラス基板を接着し、ガラス基板と電極基板にはさまれたミラ-部の存在する空間が真空である構造や、前記静電力駆動光スキャナのミラ-が、同一面内に複数個が直線的に、または平面的に配列した構造を有するものである。

【0033】この構成により、シリコン基板上に形成されたミラ-が、駆動電圧に電圧を印加することで、X軸，Y軸の2軸方向走査可能となり、半導体レーザ光は二次元走査され、全体が超小型な2軸方向走査光スキャナを提供することができる。また、複数本の静電吸引部を持つことにより、従来よりも、低電圧で、広走査角度の1軸方向走査光スキャナを提供することができる。さらに、これら光スキャナのミラ-部を、真空中で動作させることにより、高速応答が可能になる。そして、これらミラ-を単一でなく、直線的にまたは平面的に配列することで、プリンタ-の書き込み用ヘッドや光情報分野用デバイスとして、従来にない小型で全く新しい光スキャナデバイスを提供することができる。

【図面の簡単な説明】

【図1】（a）本発明の第1の実施例における小型の2軸方向走査可能な静電力駆動光スキャナの平面図
（b）同実施例における小型の2軸方向走査可能な静電力駆動光スキャナの断面図

【図2】（a）本発明の第2の実施例における小型の1軸方向走査可能な静電力駆動光スキャナの平面図
（b）同実施例における小型の1軸方向走査可能な静電力駆動光スキャナの断面図

【図3】同実施例における小型の1軸方向走査可能な静電力駆動光スキャナの動作を説明するための説明図

【図4】同実施例における小型の1軸方向走査可能な静電力駆動光スキャナの他のミラ-形状を示す平面図

【図5】本発明の第3の実施例における小型の1軸または2軸方向走査可能な光スキャナの断面図

【図6】本発明の第4の実施例における小型の1軸方向走査可能な光スキャナを複数個、直線的に配列したところを示す平面図

【図7】同実施例における小型の2軸方向走査可能な光スキャナを複数個、平面的に配列したところを示す平面図

【図8】従来のガルバノメ-タスキャナ式の2軸方向走査光スキャナの概念斜視図

【図9】従来のポリゴンミラ-とガルバノメ-タスキャナによる2軸方向走査光スキャナの概念斜視図

【図10】従来のホログラムスキャナとガルバノメ-タスキャナによる2軸方向走査光スキャナの概念斜視図

【図11】従来の静電型シリコンねじり振動子の外観図

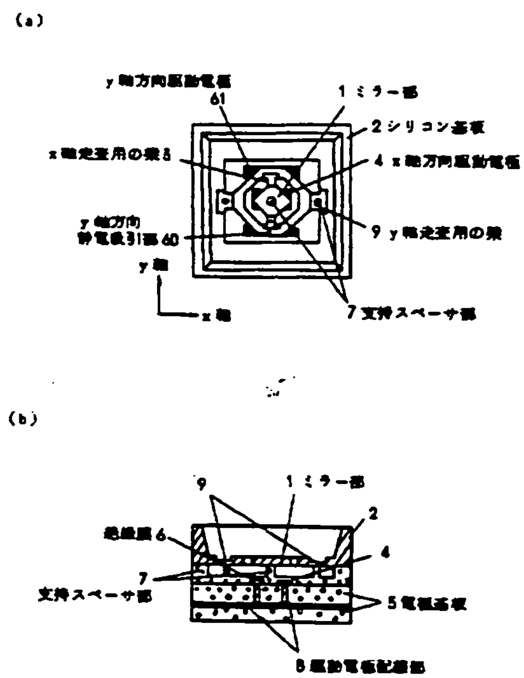
【図12】従来の静電型シリコンねじり振動子の運動状態を示した断面図

【符号の説明】

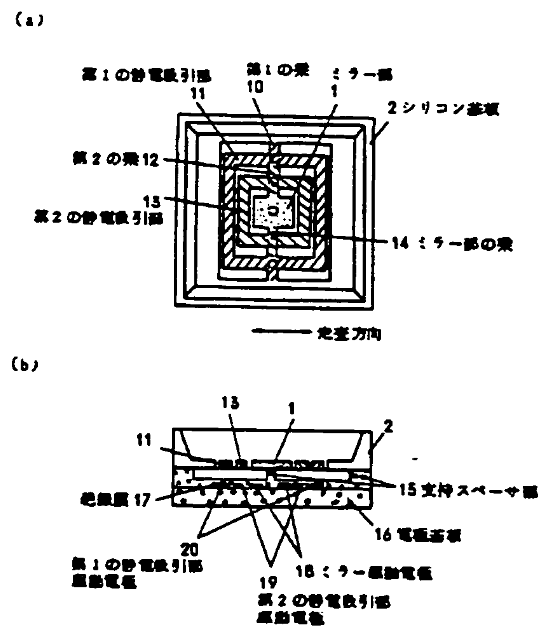
1　ミラ-部
2　シリコン基板
3　X軸走査用の梁
4　X軸方向駆動電極
5　電極基板
6　絶縁膜
7　支持スペ-サ部
8　駆動電極配線部
9　Y軸走査用の梁
10　第1の梁

１１　第１の静電吸引部
１２　第２の梁
１３　第２の静電吸引部
１４　ミラー部の梁
１５　支持スペーサ部
１６　電極基板
１７　絶縁膜
１８　ミラー駆動電極
１９　第２の静電吸引部駆動電極
２０　第１の静電吸引部駆動電極
２１　第１の静電吸引部
２２　第２の静電吸引部
２３　第３の静電吸引部
２４　第４の静電吸引部
２５　支持スペーサ部
３０　真空部
３１　ガラス基板
３２　１軸方向走査光スキャナ
３３　第１列のミラーアレイ
３４　第２列のミラーアレイ
３５　２軸方向走査光スキャナ
３６　面状配列光スキャナ
３７　Ｙ軸走査用の梁
４１　振動子
４２　可動板
４３　スパンバウンド
４４　枠
４５　ガラス基板
４６　スペーサ
５１　レーザ光源
５２　Ｘ軸方向ミラー
５３　Ｙ軸方向ミラー
５４　ポリゴンミラー
５５　ディスク型ホログラムスキャナ
６０　Ｙ軸方向静電吸引部
６１　Ｙ軸方向駆動電極

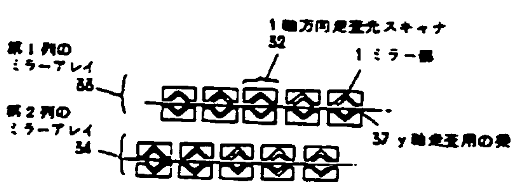
【図１】



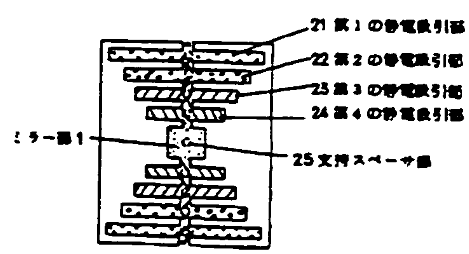
【図２】



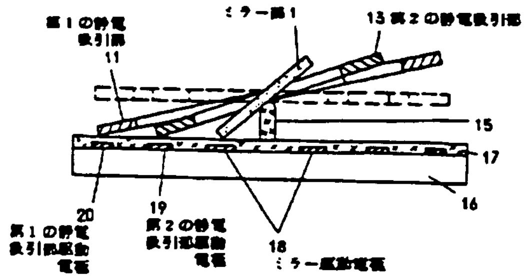
【図６】



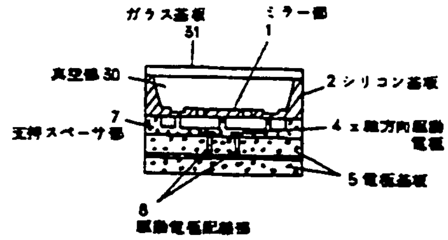
【図４】



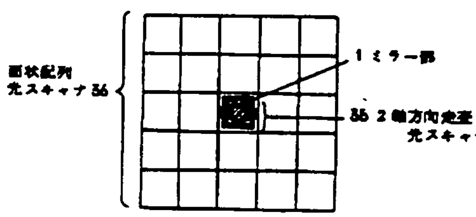
【図3】



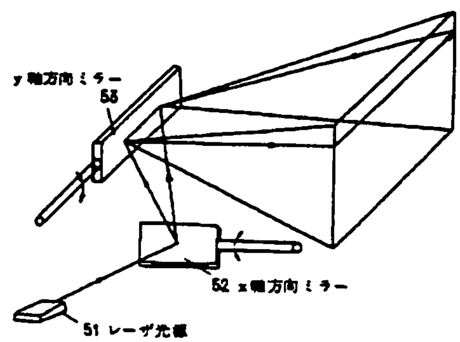
【図5】



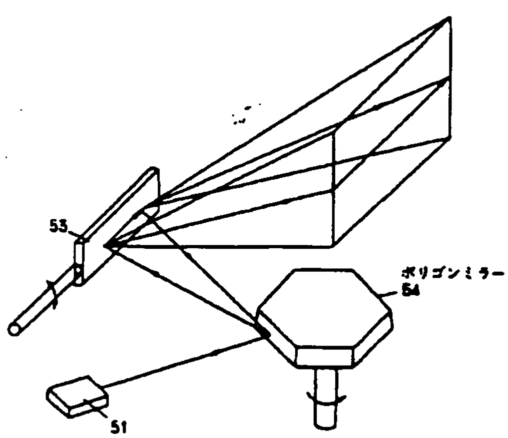
【図7】



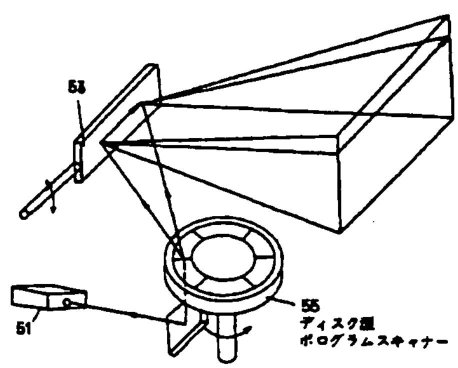
【図8】



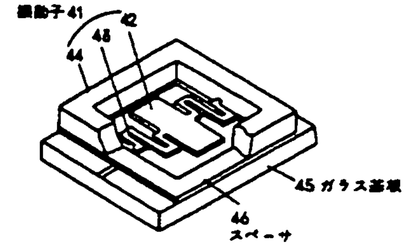
【図9】



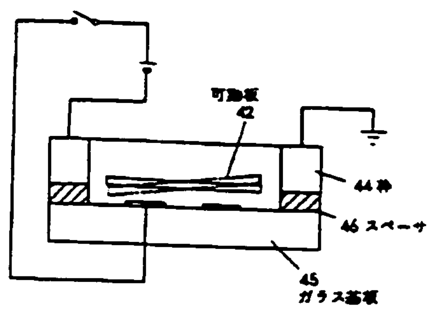
【図10】



【図11】



【図12】



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(54) Name of the Invention: COMPACT OPTICAL SCANNER DRIVEN BY ELECTROSTATIC FORCE

(57) (Summary)

(Purpose)

The purpose is to provide a compact optical scanner driven by electrostatic force relating to an optical scanner for scanning in uniaxial or biaxial direction, which can be used as a laser radar scanner for writing operations in a facsimile or in a printer, or in the optical information processing field for future applications.

The design provides an ultra-compact type of an optical scanner formed with a driving mechanism comprising a mirror, etc., used for semiconductor processing operations, thus solving the problem of large driving mechanisms and complicated constructions of prior art designs.

(Construction)

The invention provides an ultra-compact optical scanner which can be used for scanning in biaxial direction, comprising a mirror part formed with a silicon substrate enabling displacement in axial direction X and axial direction Y, reflecting semiconductor laser rays;

a beam part formed with a silicon substrate supporting the mirror part on both sides;

a driving electrode part for axial direction X and axial direction Y, positioned opposite the reverse surface of the mirror part;

an electrode substrate, and an insulating film insulating the driving electrodes;

a supporting spacer part determining the gap between the driving electrode part and the mirror part;

further comprising a wiring part for said driving electrodes, wherein the distance to the mirror part is longer than the distance to the driving electrodes;

wherein the electromagnetic force does not have an effect on the mirror part due to a planar formation.

[Figure (a) and (b)]

Figure (a)

1 mirror part
2 silicon substrate
3 beam for scanning in axial direction Y
4 driving electrode for axial direction X
7 supporting spacer part
9 beam for scanning in axial direction Y
60 electrostatic force attracting part for axial direction Y
61 driving electrode for axial direction Y
↑ axis Y
→ axis X

Figure (b)

1 mirror part
5 electrode substrate
6 insulating film
7 supporting spacer part
8 wiring part for driving electrodes

[page 2]

(Scope of the Patent's Claim)

(Claim 1)

A compact optical scanner driven by electrostatic force, characterized by a construction comprising a mirror part formed with a silicon plate displaceable in the direction of axis X, reflecting semiconductor laser light,

wherein the entire construction is integrated with said mirror part, while the thickness of the mirror part is not necessarily identical, comprising a beam (girder) used for scanning in axial direction X, formed with a silicon plate supporting a mirror part on both sides, creating a construction formed so that it is integrated with said beam for scanning in axial direction X from the outer side; forming an integrated construction with said electrostatic force attracting part, said electrostatic force attracting part displaceable in and intersecting axial direction X, and said mirror part;

wherein the thickness of the electrostatic force attracting part is not necessarily identical, comprising a beam for scanning in axial direction Y, formed with a silicon substrate supporting

an electrostatic force attracting part on both sides;

comprising driving electrodes for axial direction X and for axial direction Y arranged opposite the reverse surface of said electrostatic force attracting part and of the mirror part, used in order to operate said mirror part, an electrode substrate formed with said driving electrodes, and an insulating film insulating the driving electrodes, inserted between said mirror part and said electrode driving part, providing support so as to prevent occurrences of mirror deflection due to mirror displacement;

comprising a support spacer part determining the gap between the driving electrodes and the mirror part; as well as a wiring part for said driving electrodes, having a longer distance to the mirror part than to the driving electrodes;

in a compact optical scanner for scanning in biaxial direction formed on the planar level so that the electrostatic force does not have an effect on the mirror part.

(Claim 2)

A compact optical scanner driven by electrostatic force, characterized by a construction comprising a mirror part formed with a silicon plate displaceable in uniaxial direction, reflecting semiconductor laser light,

wherein the entire construction is integrated with said mirror part, while the thickness of the mirror part is not necessarily identical, comprising a beam part formed with a silicon substrate supporting the mirror part on both sides, creating a construction integrated with said beam part;

comprising an electrostatic force attracting part formed with a plurality of elements (groups, stages) used in order to generate torsion induced in the beam part independently from said mirror part;

a driving electrode part positioned opposite said electrostatic force attracting part and said mirror part, an electrode substrate formed with said driving electrodes, and an insulating film which serves to insulate the driving electrodes, inserted between said mirror part and said driving electrodes, providing support so as not to create deflection as a result of mirror displacement;

in a compact optical scanner for scanning in uniaxial direction, comprising a supporting spacer part determining the gap between the driving electrodes and the mirror part.

(Claim 3)

The optical scanner driven by electrostatic force described in claim 1 and claim 2, characterized by the fact that a film preventing reflection on the mirror part is bonded to an

attached glass substrate, wherein a space existing in the mirror part which is sandwiched between the electrode substrate and the glass substrate is vacuum.

(Claim 4)

The optical scanner driven by electrostatic force described in claim 1 and claim 2, characterized by the fact that a plurality of mirrors is arranged within the same plane with a linear or planar arrangement.

(Detailed Explanation of the Invention)

(0001)

(Sphere of Industrial Use)

(0001)

This invention relates to an optical scanner for scanning in biaxial direction or uniaxial direction. The scanner can be used in fields requiring processing of optical information, represented for instance by future optical computing, or for writing with a printer or with a facsimile while using a laser radar scanner in order to probe objects and grasp relevant information.

(0002)

The following is an explanation of an optical scanner according to prior art shown in Figures 8, 9, and 10, which can be used for biaxial scanning. As shown in Figure 8, 9, and 10, number 51 indicates a source of laser light, 52 is a directional mirror for axial direction X, 53 is a directional mirror for axial direction Y, 54 is a polygon mirror, and 55 is a disk typ of a hologram scanner. The following is an explanation of the operation of an optical scanner for scanning in the biaxial direction which has the above described construction. Biaxial scanning can be conducted as shown in Figure 8 because laser light supplied from laser light source 51 will be affected by rotary displacement in axial direction X of mirror 52 and in axial direction Y of mirror 53. This construction can be also combined with a galvanometer construction shown in Figure 9, creating a combined construction including Y-axis direction mirror 52 providing rotational displacement with a galvanometer scanner and with a polygon mirror. Another known construction is the construction shown in Figure 10 in which a Y-direction mirror 53 which creates rotational displacement is combined with a galvanometer scanner and with a disc type hologram scanner 55.

(0003)

Great progress has been achieved in recent years also in research related to micro-

machines, in particular in the area of uniaxial scanning performed with optical scanners. Small, compact types of optical scanners have been manufactured for silicon micro-machining applications, for instance as described in Selected Lectures from the 68th National Conferences of the Japan Association for Mechanical Sciences, Electrostatic Silicon Torsional Oscillation Element [Seidenkei Shirikon Nejiri Shindoshi] (Nakagawa et al., Fuji Electronics), Vol. D, (1990), etc.

(0004)

The following explanation pertains to a compact optical scanner used for uniaxial scanning according to prior art based on Figure 11 and Figure 12. Figure 11 is a diagram showing an external view of an electrostatic torsional oscillation element. Oscillation element 41 comprises a mobile plate 42, a span bound 43, and a frame 44, creating an integrated formation which can be etched from a silicon plate which is 0.3 mm thick. The thickness of mobile plate 42 and of span bound 43 is 20 μm. Silicon oscillation element 41 is formed with a spacer 46 which is inserted in glass plate 45 forming an electrode.

(0005)

Figure 12 shows a profile view of an electrostatic silicon oscillation element indicating its mode of operation. When voltage is applied between an electrode and mobile plate 42 which is supported by an S-shaped span bound 43, electrostatic force will be having an effect between both elements, creating oscillations by an electrostatic attraction in the electrode while span bound 43 forms the axis of mobile plate 42.

(0006)

(Problems To Be Solved By This Invention)

However, when the above described construction is used with an optical scanner for biaxial scanning, this creates a complicated construction consisting of many parts and it is difficult to achieve a compact design in this manner.

(0007)

Although an electrostatic torsional oscillation element is small, it cannot be used for biaxial scanning. Moreover, even when only an optical scanner for uniaxial scanning is taken into consideration, a high driving voltage will be required for an increased scanning angle.

[page 3]

Conversely, when the scanning angle is increased to the limit of the driving voltage, this creates problems such as a reduced mechanical strength of the span bound, etc.

(0008)

The purpose of this invention is to solve the above mentioned problems related to prior art by providing an optical scanner for uniaxial or biaxial scanning with a low driving voltage (for a wide scanning angle), which has a compact design that can be formed with part such as an actuator, a mirror, etc., and which can be used during semiconductor processing.

(0009)

(Means To Solve Problems)

In order to achieve the above mentioned purpose, this invention provides a construction comprising a mirror part formed with a silicon substrate displaceable in the direction of axis X and axis Y, reflecting semiconductor laser light, a beam part formed with a silicon substrate supporting a mirror part on both side, driving electrodes for the Y-axis direction driving and driving electrodes for the X-axis direction arranged opposite the reverse surface of the mirror part in order to drive said mirror part, as well as an electrode substrate formed with said driving electrodes, an insulating film which serves to insulate the driving electrodes deployed between said mirror part and said driving electrodes, forming a supporting spacer part determining the gap between the mirror part and the driving electrode.

Furthermore, because the distance of the wiring part to said driving electrodes is longer than the distance between of the driving electrodes to the mirror part, this creates the construction of an optical scanner enabling scanning in biaxial direction formed on a flat surface without effecting the mirror part, integrated with the construction of the beam part;

provided with an electrostatic force attracting part formed from a plurality of elements (groups, stages) in order to generate torsion in a beam (girder) part independently from the mirror part;

in an optical scanner part enabling scanning in uniaxial direction with a construction formed with driving electrodes arranged opposite said electrostatic force attracting part and said mirror part;

and with a glass substrate which is bonded to a reflection preventing film in the mirror part in a construction wherein a vacuum is created in the mirror part which is sandwiched between the electrode substrate and the glass substrate,;

wherein the mirror of said optical scanner which is driven by electrostatic force has a construction comprising multiple elements arranged on the linear or planar level within the same plane.

(0010)

(Operation)

In accordance with the above described construction of this invention which has a mirror formed on a silicon substrate, when a voltage is applied to the driving electrodes, this makes it possible to conduct biaxial driving operation in the direction of axis X and axis Y, enabling two-dimensional scanning with semiconductor laser rays. This invention thus makes it possible to provide an optical scanner for bidirectional scanning with an extremely compact design of the entire construction. In addition, because the construction supports a plurality of electrostatic force attracting parts, this makes it possible to provide an optical scanner for uniaxial scanning with a wide angle by using a lower voltage than the voltage used according to conventional constructions. Moreover, because the mirror parts of the optical scanner can be operated in a vacuum, this provides for a fast response characteristics. Further, because the mirrors do not use a single array arrangement but rather a linear or planar array arrangement, this makes it possible to achieve a smaller size which could not be achieved according to prior art by providing a completely novel type of an optical scanning device.

(0011)

(Embodiments)

(Embodiment 1)

The following is an explanation of Embodiment 1 of this invention which is based on the reference provided in the figures. Figure 1 shows a view of a compact optical scanner according to an embodiment of this invention which is driven by electrostatic force and which is capable of scanning in biaxial direction. Figure 1 (a) shows a top view and Figure 1 (b) shows a profile view of the scanner.

(0012)

As shown in Figure 1, number 1 indicates a mirror part, 2 is a silicon substrate part, 3 is a beam part, 4 is a driving electrode for axial direction X, 5 is an electrode substrate, 6 is an insulating film, 7 is a supporting spacer part, 8 is a wiring part for driving electrodes, 9 is a beam for scanning in axial direction Y, 60 is a part attracting electrostatic force in axial direction Y, and 61 is a driving electrode for axial direction Y. The construction of mirror part 1 is integrated with beam 3 for scanning in axial direction X. In addition, the other end of beam 3 for scanning in axial direction X is integrated with the construction of electrostatic force attracting part 60 for axial direction Y and this electrostatic force attracting part 60 for axial direction Y is formed integrated with beam 9 for scanning in axial direction Y. Moreover, the other end of beam 9 for scanning in axial direction Y is integrated with the construction of silicon substrate 2 and all of these parts are formed from silicon. Driving electrode 4 for axial direction X is arranged below mirror part 1 and driving electrode 61 for scanning in axial direction Y is arranged below electrostatic force attracting part 60 for axial direction Y and these driving electrode are formed

on electrode substrate 5.

Wiring part 8 for the driving electrodes is formed so that its distance to mirror part 1, etc., is greater than the distance to the driving electrodes and to ensure that the electrostatic force generated by wiring part 8 for the driving electrodes will not affect mirror part 1, the construction is formed with the wiring in the inner part of electrode substrate 8.

(0013)

Insulating film 6 which serves to insulate the driving electrodes and which supports mirror part 1 is formed between electrostatic force attracting part 60 for axial direction Y and mirror part 1, while supporting spacer part 7 is formed so that it determines the gap between the driving electrodes and mirror part 1. Supporting spacer part 7 is formed on electrode substrate 5 and a silicon substrate 2 is bonded to this supporting spacer part 7.

(0014)

The following is an explanation of the operation of a compact optical scanner which is driven by electrostatic force, enabling scanning in biaxial direction with the above described construction.

(0015)

When a voltage is applied to driving electrode 4 for axial direction X of mirror part 1, an electrostatic force will be received and scanning operations will be conducted with light applied in axial direction X, wherein the supporting point is formed by supporting spacer part 7 and beam 3 for scanning in axial direction X. Next, when a voltage is applied to driving electrode 61 for axial direction Y, electrostatic force attracting part 60 for axial direction Y will receive this electrostatic force and scanning operations will be conducted with the light applied in axial direction Y while a supporting point is formed by supporting spacer part 7 and by beam 9 for scanning in axial direction Y. Because mirror part 1 is integrated with electrostatic force attracting part 60 for axial direction Y, the scanning will be conducted with the scanning light in axial direction Y. Scanning can thus be conducted in both axial directions with light which is reflected from mirror part 1.

(0016)

Since in accordance with the above explained embodiment, a voltage is applied to the driving electrodes in axial direction X and axial direction Y with a mirror part 1 which is formed on a silicon substrate 1, this makes it possible to provide a compact type of an optical scanner which is driven by electrostatic force and which enables scanning with the laser light in both axial directions.

(0017)

(Embodiment 2)

This following is an explanation of Embodiment 2 of this invention based on the reference provided in the figures. Figure 2 shows a compact optical scanner according to Embodiment 2 of this direction which is driven by electrostatic force and which enables scanning in 1 axial direction. Figure 2 (a) shows a top view, and Figure 2 (b) shows a profile view of the scanner.

(0018)

As shown in Figure 2, number 1 is a mirror part, 2 is a silicon substrate, 10 is a first beam, 11 is a first electrostatic force attracting part, and 12 is a second beam.

[page 4]

Number 13 indicates a second electrostatic force attracting part, 14 is a beam for the mirror part, 15 is a supporting spacer part, 16 is a an electrode substrate, 17 is an insulating film, 18 is a mirror driving electrode, 19 is a second electrostatic force attracting electrode, and 20 is a driving electrode of the first electrostatic force attracting part. Because mirror part 1 is formed on silicon substrate 2 integrated with beam 14 of the mirror part, beam 14 is formed integrated with the mirror part, and the second electrostatic part 13 and the second beam 12 are formed so as to surround said mirror part 1. In addition, the first beam 10 and the first electrostatic force attracting part 11 are formed to surround said second electrostatic force attracting part 13 in a construction integrated with the second beam 12.

(0019)

As shown in Figure 2 (b), mirror driving electrode 18 is deployed in the part below mirror part 1. In the same manner, driving electrode 19 for the second electrostatic force attracting part 19 is formed in the part below the second electrostatic force attracting part 13, and driving electrode 20 for the first electrostatic force attracting part is formed in the part below the first electrostatic force attracting part 11. These driving electrodes are formed on electrode substrate 16. Insulating film 7 is formed between silicon substrate 2 and electrode substrate 16, and supporting spacer part 15 is formed so as to determine the gap between mirror part 1 and driving electrodes and so as to support mirror part 1. Supporting spacer part 15 is formed on electrode substrate 16 and silicon substrate 2 is bonded to supporting spacer part 15.

(0020)

The above explained construction pertained to a compact optical scanner which is driven by electrostatic force and which enables scanning in 1 axial direction. The following explanation

of the operation of this scanner is based on Figure 3. Figure 3 is a diagram explaining the operation of a compact optical scanner driven by electrostatic force for driving in 1 axial direction.

(0021)

As shown in Figure 3, when a voltage is applied to driving electrode 20 for the first electrostatic force attracting part, electrostatic force is applied to the first electrostatic force attracting part 11 which will adhere to driving electrode 20 for the first electrostatic force attracting part. At this point, the second electrostatic force attracting part 13 and the mirror part 1 will be displaced by the same amount of displacement as the first electrostatic force attracting part 11. Next, when voltage is applied to driving electrode 19 for the second electrostatic force attracting part, electrostatic force will be applied to the second electromagnet force attracting part 13 which will adhere to driving electrode 19 for the second electrostatic force attracting part. At this point, mirror part 1 will be displaced only by a displacement amount which is identical to the second electrostatic force attracting part 13. In addition, when a voltage is applied to mirror driving electrode 18, attracting force will be applied to mirror part 1 which will adhere to mirror driving electrode 18. Due to the above described operation, only mirror part 1 can be driven with a low voltage as a single unit. In addition, this also makes it possible to obtain a wide scanning angle because torsion is generation in very small increments with each of the beam parts while the same voltage is applied.

(0022)

Figure 4 shows a top view of the status of another mirror part shape of a compact optical scanner which is driven by electrostatic force and enables scanning in 1 axial direction according to Embodiment 2 of this invention. As shown in Figure 4, 1 is a mirror part, 21 is the first electrostatic force attracting part, 22 is the second electrostatic force attracting part, 23 is the third electrostatic force attracting part, 24 is the fourth electrostatic force attracting part, and 25 is a supporting spacer part.

(0023)

Also with this shape, when voltage is applied sequentially from the first electrostatic force attracting part to the fourth electrostatic force attracting part, mirror part 1 can be operated with a low driving voltage and a wide scanning angle can be obtained. Moreover, although the present embodiment used a divided construction in which the driving electrodes corresponded to the electrostatic force attracting part, it is also possible to create one electrode for the entire construction. However, although the construction will be more complicated when it is separated, this type of construction makes it possible to exercise the driving control to a higher extent.

(0024)

Because according to the above explained embodiment, a plurality of electrostatic force attracting parts is formed on the periphery of mirror part 1 which is formed on silicon substrate 1, when a voltage is applied sequentially through driving electrodes corresponding to a plurality of electrostatic force attracting parts and said mirror part 1, the driving operations can be conducted with a lower voltage than during driving operations using a single unit of mirror part 1 according to prior art. Furthermore, this also makes it possible to provide a compact optical scanner, driven by electrostatic force and enabling scanning in uniaxial direction while scanning can be attained with a wide scanning angle.

(Embodiment 3)

The following is an explanation of Embodiment 3 of this invention based on the enclosed reference figures. Figure 5 shows a profile view of a compact optical scanner enabling uniaxial or biaxial scanning according to Embodiment 3 of this invention. As shown in Figure 5, 1 is a mirror part, 2 is a silicon substrate, 4 is a driving electrode for axial direction X, 5 is an electrode substrate, 7 is a supporting spacer, 8 is a wiring part for electrode wiring, 30 is a vacuum part, and 31 is a glass substrate.

(0025)

The driving electrode 4 for axial direction X and wiring part 8 of the driving electrode are formed on electrode substrate 5. Moreover, supporting part 7 is formed on top of that, and silicon substrate 2 having a mirror part 1 is bonded to said supporting spacer part 7. Further, the surface side opposite the surface, bonded to supporting spacer part 7 of silicon substrate 2, is joined to glass substrate 31 with an attached reflection preventing film. Anode joining can be used as the joining method to join glass substrate 31 with silicon substrate 2 in a vacuum chamber.

(0026)

When a voltage is applied to the driving electrode with the above mentioned construction, mirror part t 1 will be operated while the response characteristics are improved because the operation is conducted in a vacuum. Also, the mirror surface of mirror part 1 can be maintained free of oxidation. Further, because glass substrate 31 is formed on the surface of mirror part 1, this is represents an effective measure against contamination, etc.

(0027)

As was explained in the above embodiment, because the space existing in one part of the mirror which is sandwiched between the glass plate and the electrode substrate is vacuum, this improves the responsiveness of the operations of the mirror part and it also makes it possible to provide a compact optical scanner capable of scanning in uniaxial or biaxial direction with a strong preventive measure preventing contamination or oxidation of the mirror surface.

(0028)

(Embodiment 4)

The following is an explanation of Embodiment 4 of this invention based on the reference provided in the figures. Figure 6 shows a top view indicating the linear arrangement of a plurality of compact optical scanners enabling scanning in uniaxial direction according to Embodiment 4 of this invention.

(0029)

As shown in Figure 6, 1 is a mirror part, 32 is an optical scanner for scanning in uniaxial direction, 33 is a first mirror array, 34 is a second mirror array, and 37 is a beam supporting scanning in axial direction Y. As shown in Figure 6, optical scanner 32 for scanning in uniaxial direction thus has mirror part 1 which is supported by beam 37 for scanning in axial direction Y with an arrangement creating the first mirror array 33.

[page 5]

In addition, the second mirror array 34 is deployed opposite the first mirror array 33 in the same arrangement as that of the first array of mirror array 33. This makes it possible to initiate operations which will be equivalent to the arrangement of mirror part 1 with a higher density by shifting the arrangement by 1/ 2 pitch in mirror part 1. The design of this arrangement can be used for a writing head in a printer, etc.

(0030)

Figure 7 shows a top view indicating the planar arrangement of a plurality of optical scanners enabling scanning in biaxial scanning direction with a compact scanner according to Embodiment 4 of this invention. As shown in Figure 7, 1 is a mirror part, 35-is an optical scanner for scanning in biaxial direction, and 36 indicates the surface shape arrangement of the optical scanner. The construction of the arrangement of the surface shape of optical scanner 36 is formed with a planner arrangement of optical scanner 36 for biaxial scanning which has a mirror part 1 in the center. This surface shape arrangement of the optical scanner 36 can be used in a very thin display, or the use as an optical information processing element is also conceivable for the purposes of optical computing.

(0031)

As was explained above, this embodiment provides a novel type of a compact optical scanner device through a planar or linear arrangement of a plurality of optical scanners in a biaxial or uniaxial scanner which was not available with a single optical scanner.

(0032)

(Effect of the Invention)

As was explained above, this invention provides a construction comprising a mirror part formed with a silicon substrate which can be displaced in the axial direction of axis X and axis Y, reflecting semiconductor laser rays, and a supporting beam part is formed with a silicon substrate supporting the mirror part from both sides,

wherein in order to operate said mirror part, driving electrodes for driving in axial direction X and in axial direction Y are deployed opposite the reverse surface of the mirror part, comprising an insulating film insulating the driving electrodes, inserted between said mirror part and said driving electrodes, and a supporting spacer part determining the gap between the driving electrode part and the mirror part.

Further, the distance between the wiring part and said driving electrode part is longer than the distance from the driving electrodes to the mirror in a construction of an optical scanner enabling scanning in biaxial direction formed with a flat surface shape wherein the electrostatic force is not affecting the mirror part, formed in an integrated construction with the supporting beam part.

Torsion is thus generated in the beam part independently from the mirror part in a construction comprising a plurality of (groups, stages) of the formed electrostatic force attracting parts in an optical scanner enabling scanning in uniaxial direction with the construction of the formed driving electrodes deployed opposite said electrostatic force attracting part and said mirror part, while a glass substrate is bonded to a film preventing reflection on the surface of the mirror part.

The construction also comprises vacuum created in a space in the mirror part sandwiched between the glass substrate and the electrode substrate, while the mirrors of said optical scanner which is driven by electrostatic force are arranged in a linear or planar arrangement of a plurality of elements constructed within the same plane.

(0033)

As a result of the above described construction, when a voltage is applied as a driving voltage to the mirror formed on the silicon substrate, enabling biaxial scanning in axial direction X and axial direction Y, semiconductor laser light can be used for two dimensional scanning. This makes it possible to provide an optical scanner for scanning in biaxial direction which has an ultra-compact construction. In addition, because the construction supports a plurality of electrostatic force attracting parts, this makes it possible to provide an optical scanner for uniaxial scanning which can be used with a wider angle and with a lower voltage than according to prior art constructions. Moreover, a high response speed is enabled thanks to the fact that the

mirror parts of this optical scanner can be operated in vacuum. Further, since this is not a single mirror part but an array which is arranged in a linear or planar arrangement, this makes it possible to provide a completely novel type of a compact optical scanner not available according to prior art as a device which can be used in the optical information field, or as a writing head in a printer, etc.

(Brief Explanation of Figures)

(Figure 1)

(a) A top view of a compact optical scanner which is driven by electrostatic force enabling scanning in biaxial scanning direction according to Embodiment 1 of this invention;

(b) a profile view of a compact optical scanner which is driven by electrostatic force enabling scanning in biaxial scanning direction according to the same embodiment.

(Figure 2)

A top view of a compact optical scanner which is driven by electrostatic force enabling scanning in uniaxial scanning direction according to Embodiment 2 of this invention;

(b) a profile view of a compact optical scanner which is driven by electrostatic force enabling scanning in uniaxial scanning direction according to the same embodiment.

(Figure 3)

A diagram explaining the operation of a compact optical scanner driven by electrostatic force enabling scanning in uniaxial scanning direction according to the same embodiment.

(Figure 4)

A top view indicating another mirror shape of a compact optical scanner driven by electrostatic force enabling scanning in uniaxial direction according to the same embodiment.

(Figure 5)

A profile view of a compact optical scanner enabling uniaxial or biaxial scanning according to Embodiment 3 of this invention.

(Figure 6)

A top view indicating a detail of the linear arrangement of a plurality of compact optical scanners enabling scanning in uniaxial direction according to Embodiment 4 of this invention.

(Figure 7)

A top view indicating the detail of the planar arrangement of a plurality of compact optical scanners enabling scanning in biaxial direction according to the same embodiment.

(Figure 8)

A perspective view of a scanner enabling scanning in biaxial direction with a conventional galvano meter scanner method.

(Figure 9)

A perspective view explaining the concept of an optical scanner for scanning in biaxial direction with a galvanometer scanner and polygon mirror according to prior art.

(Figure 10)

A perspective view explaining the concept of an optical scanner for scanning in biaxial direction with a galvanometer scanner and hologram scanner according to prior art.

(Figure 11)

An external perspective view of a silicon torsion oscillation element of the electrostatic type according to prior art.

(Figure 12)

A profile view indicating the operating status of a silicon torsion oscillation element of the electrostatic type according to prior art.

(Explanation of Codes)

1 mirror part,
2 silicon substrate,
3 beam for scanning in axial direction X,
4 electrode for driving operations in axial direction X,
5 electrode substrate,
6 insulating film,
7 supporting spacer part,
8 wiring part for driving electrodes,
9 supporting beam for scanning in axial direction Y,
10 the first supporting beam,

[page 8]

11 the first electrostatic force attracting part,
12 the second supporting beam,
13 the second electrostatic force attracting part,
14 mirror part supporting beam,
15 supporting spacer part,
16 electrode substrate,
17 insulating film,
18 mirror driving electrode,
19 the second electrostatic force attracting part driving electrode,
20 the first electrostatic force attracting part driving electrode,
21 the first electrostatic force attracting part,
22 the second electrostatic force attracting part,
23 the third electrostatic force attracting part,
24 the fourth electrostatic force attracting part,
25 supporting spacer part,
30 vacuum part,
31 glass substrate,
32 optical scanner for scanning in uniaxial direction,
33 the first mirror array,
34 the second mirror array,
35 optical scanner for scanning in biaxial direction,
36 optical scanner with surface shape arrangement,
37 supporting beam for scanning in Y direction,
41 oscillation element,
42 mobile plate,
43 span bound,
44 frame,
45 glass substrate,
46 spacer,
51 source of laser light,
52 mirror for axial direction X,
53 mirror for axial direction Y,
54 polygon mirror,
55 disk type hologram scanner,
60 electrostatic force attracting part in axial Y,
61 driving electrode for axial direction Y.

Figure 1 (a), (b), Figure 2, (a), (b), Figure 4 and Figure 6.

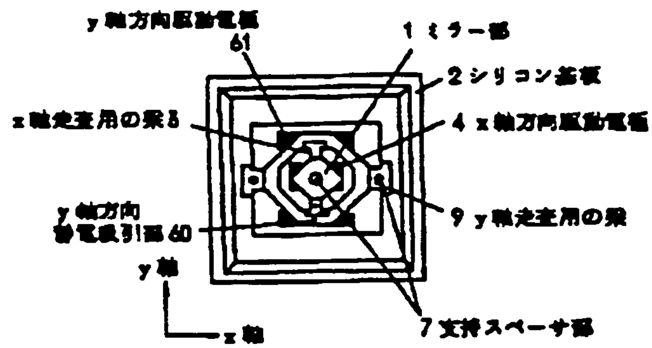
(Figure 1 a and b)

(a)

1 mirror part
2 silicon substrate
3 beam for scanning in Y direction
4 driving electrode for X direction
7 supporting spacer part
60 electrostatic force attracting part for axial direction Y
↑ Y direction
→ X direction

【図1】

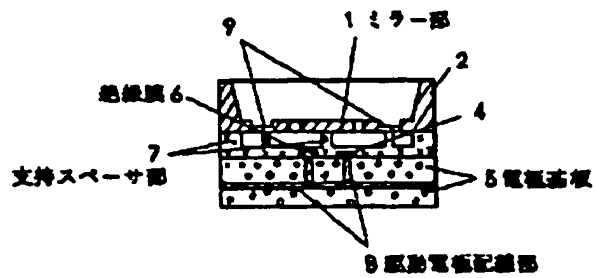
(a)



(b)

1 mirror part
5 electrode substrate
6 insulating film
7 supporting spacer part

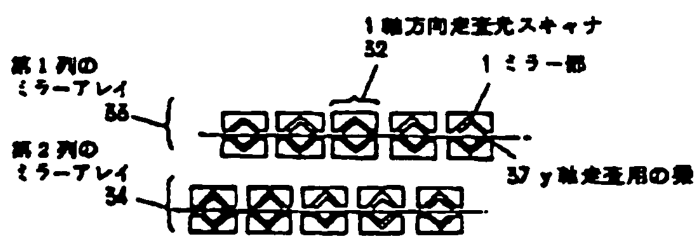
(b)



(Figure 6)

1 mirror part
2 second mirror array
32 optical scanner for scanning in uniaxial direction
33 first mirror array
34 second mirror array
37 beam for scanning in axial direction Y

【図6】



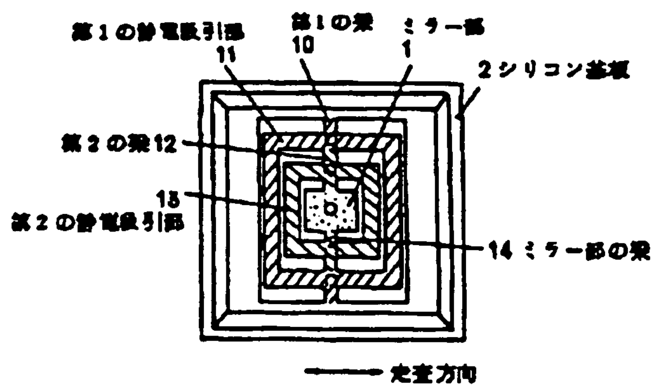
(Figure 2)

【図2】

(a)

1 mirror part
2 silicon substrate
10 the first beam
11 the first electrostatic force attracting part
12 the second beam
13 the second electrostatic force attracting part
14 beam for the mirror part
<–> scanning direction

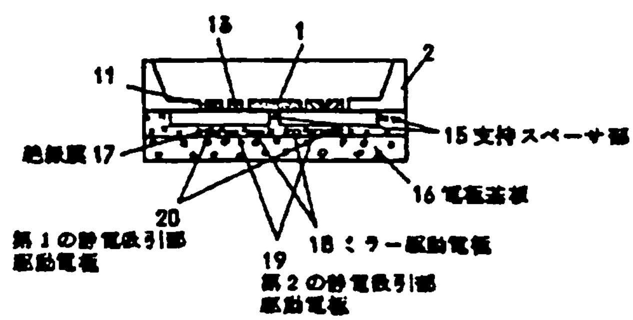
(a)



(b)

15 supporting spacer part
16 electrode substrate
17 insulating film
18 mirror driving electrode
19 the second electrostatic force attracting part
20 the first electrostatic force attracting part

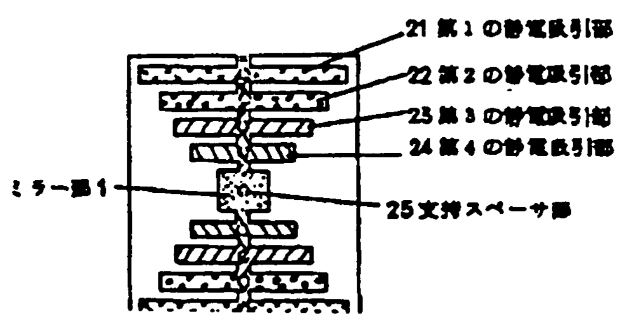
(b)



(Figure 4)

【図4】

1 mirror
21 the first electrostatic force attracting part
22 the second electrostatic force attracting part
23 the third electrostatic force attracting part
24 the fourth electrostatic force attracting part
25 supporting spacer part



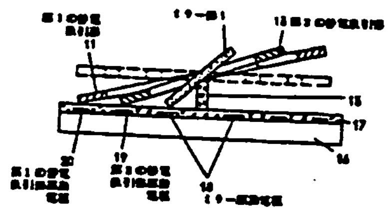
[page 7]

Figure 3, Figure 5, Figure 7, Figure 8, Figure 9, Figure 10

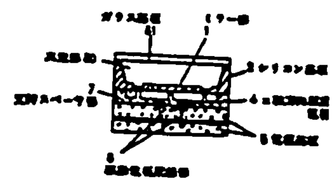
[page 8]

Figure 12

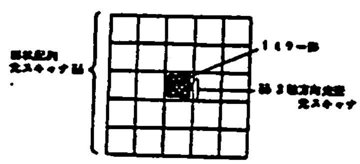
【図3】



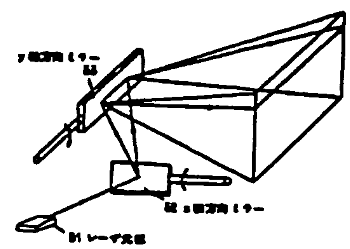
【図5】



【図7】



【図8】



(Figure 3)

1 mirror part
11 the first electrostatic force attracting part
13 the second electrostatic force attracting part
18 mirror driving electrode
19 the second electrostatic force attracting part driving electrode
20 the first electrostatic force attracting part driving electrode

(Figure 5)

1 mirror part
2 silicon substrate
4 driving electrode for axial direction X
5 electrode substrate
7 supporting spacer part
8 driving electrode substrate
30 vacuum part
31 glass substrate

(Figure 7)

1 mirror part
35 optical scanner for scanning in biaxial direction
36 surface shape arrangement of optical scanner

(Figure 8)

51 laser light source
52 mirror for axial direction X
53 mirror for axial direction Y

(Figure 9)

54 polygon mirror

(Figure 10)

53 disk type of hologram scanner

(Figure 11)

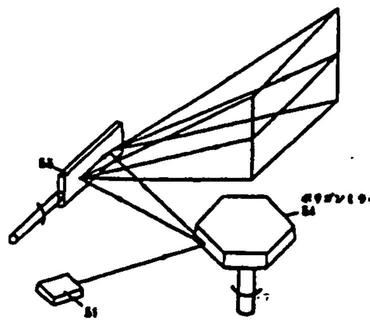
41 oscillation element
45 glass substrate
46 spacer

[page 8]

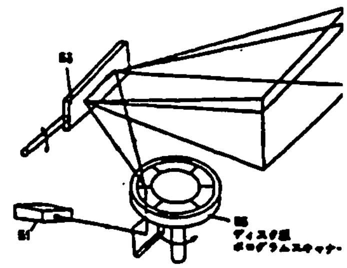
(Figure 12)

42 mobile plate
44 frame
46 spacer
45 glass substrate

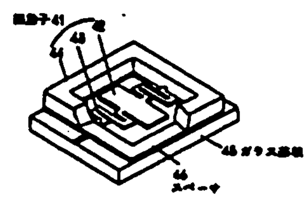
【図9】



【図10】



【図11】



【図12】